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Interactive comment on "Using MODIS land surface temperatures and the Crocus snow model to understand the warm bias of ERA-Interim reanalyses at the surface in Antarctica" *by* H. Fréville et al.

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Page 61, line 26. The raw resolution of ERA-Interim is not 0.5° but 0.75°. How do the authors deal with the topography when they interpolate the ERA-Interim temperature at 25 km of resolution ? Is the temperature corrected (with a constant lapse rate) for taking into account the sub-grid topography ? If it is not the case, what is the difference between the 0.75x0.75 interpolated topography with the 25 km MODIS topography? Idem with the forcing fields (T2m, Q2m, WS10m, ...) of CROCUS ?

Answer : The ERA-interim fields (both surface temperature and forcing meteorological conditions) were extracted at 0.5° resolution, using the bilinear interpolator implemented in the ECMWF MARS server. In the submitted paper, no corrections were applied to take into account the difference between the ERA-interim topography interpolated at 0.5° and the actual topography of the 25 km stereopolar grid. This topography comes from Bamber, J; Gomez-Dans, JL, 2005. Radarsat Antarctic Mapping Project Digital Elevation Model Version 2. Boulder, Colorado USA: National Snow and Ice Data Center. This step of projection aims mainly at facilitating the comparison between the datasets. It is not to improve the resolution of ERA Interim. This point will be clarified in the revised paper.

The difference between both topographies (ERA-interim elevation minus stereo polar grid elevation) is shown on Figure R1.1. Figure R1.1 shows that the difference is very small (typically less than 50 m) over a very large part of the Antarctic Plateau, due to the flatness of the ice-sheet. The difference shows no significant bias (both positive and negative values coexist), which excludes that the ERA-interim Ts warm bias could stem from differences between ERA-interim topography and the actual topography of the ice-sheet. Obviously, there are important differences at the ice-sheet margin and in mountainous areas. For several reasons, these regions were excluded from the scope of the paper (i.e. the accuracy of the reanalyses and their interpolation on a finer grid is limited by high climate gradients at the margin). Applying directly a lapse rate to surface temperature is less common than to air temperature since no related data have been yet published, according to our knowledge. However, in order to answer the question, we show on Figure R1.2 the surface temperature difference between 2 configurations of Crocus simulations : the one considered in the paper, taking not into account the difference of elevation, and a second one where ERA-interim meteorological forcing conditions were corrected to take into account the difference in elevation according to the method described in Cosgrove et al.(2003) and applied to Crocus simulations over Northern Eurasia in a previous study (Brun et al., 2013). This method changes the air temperature according to the standard atmospheric lapse rate, the pressure, the specific humidity and the long-wave downwards radiation accordingly. The difference in surface temperature between both simulations is very low over the Plateau, generally between -0.5 and +0.5°C, showing that a difference in elevation between ERA-interim and the actual topography cannot explain the warm bias detected over the Plateau.

2. pg 62, line 27: CROCUS is forced by T2m from ERA-Interim which is impacted by the "warm bias" in surface as explained in the paper. But, in respect to in-situ observations, what is the bias of T2m from ERA-Interim in respect to ERA-Interim based TS vs in-situ TS. I guess that the authors have also the observed T2m from the compared weather stations. Due to errors compensations, TS could be biased but not T2m in some models.

Answer : Measuring in situ air temperature in Antarctica is much more error-prone than surface temperature, even at stations with permanent staff. Using different sensors at Dome C, Genthon et al (2010) documented the significant warming of the sensors by solar radiation when wind velocity is low and when the sensor is not artificially ventilated. Using a vertical profile of observed air temperature, they already documented a warm bias of ERA-interim air temperature. Recently, Jones and Harpham (2013) have shown that the largest difference between ERA-interim and the HadCRUT4 T2m (gridded data set interpolated from in-situ T2m observation) is a warm bias over the Antarctic Plateau. With a courtesy of Dr. Phil Jones, we reproduce in Figure R1.3 a sub-sample of Figure 2 published in their paper.

Measuring air temperature over the Antarctic Plateau at stations where no permanent staff can perform maintenance is even more challenging. There are additional issues, among which the riming of the shelter and the changing elevation of the sensor between visits, due to snowfall accumulation, riming/sublimation and occasional snow drift deposits or erosion. In spite of these limitations, we compare in Figure R1.4 ERA-interim T2m with air temperature, as they are, for Kohnen (AWS9), Plateau Station B (AWS12), Pole of Inacessibility (AWS13) and Princess Elisabeth (AWS16). Note that in left column the air temperature is the temperature as measured on the AWS at a

level above the surface between 2 and 4 m, changing with accumulation. The 2 m temperature (right column) is determined from the AWS observations based on a energy balance model. Stability values determined in this model are used to correct the air temperature values to a fixed height of 2 m above the surface. Due to problems with the wind speed sensor we were not able to correct the air temperature at Pole of Inacessibility (AWS13). The height above the surface of that sensor is about 4 m, and not changing much. Note that the energy balance calculations developed at Institute for Marine and Atmospheric Research Utrecht, University of Utrecht, are not published.

Figure R1.4 unambiguously shows that ERA-interim air temperature at 2m exhibits a positive bias from 1,93 to 3,68°C at all stations located on the Plateau. This bias is consistent with the positive bias of Ts revealed both from MODIS Ts and in situ Ts. For Kohnen (AWS9), Plateau Station B (AWS12) and Pole of Inacessibility (AWS13), the cloud of points exhibits a particular feature: for the coldest observed temperatures, ERA-interim T2m stay systematically warmer than in situ observations. The same feature appears also for Ts (Figure 5 of the submitted version of the paper). Indeed, these cases correspond to meteorological situations with the more stable boundary layer, showing once more the mentioned weakness in the ERA-interim parameterization of turbulent fluxes. In contrast to stations located on the Plateau, Princess Elisabeth station (AWS16) is located in a coastal and mountainous region which strongly limits the validity of comparing the ERA-Interim interpolated T2m with a local station. In order to strengthen the conclusions of our study, the revised version of the paper will mention the biases and features displayed in R1.4 and will add this new figure.

3. Even if CROCUS is forced by a too high T2m, CROCUS is able to correct in part the warm bias. This could be strange and could be due to some errors compensations. To prove that CROCUS work well with unbiased inputs (and I am sure that it is the case), CROCUS needs to be forced by in-situ measurements as validation and the resulting modelled Ts needs to be compared to the observed one.

Answer : It is very difficult to obtain a timeseries of in situ measurements to run Crocus over a long period of time owing to the measurements conditions in Antarctica. First, there are uncertainties regarding the measurement levels of the 2-meter air temperature and the 10- meter wind speed which may vary according to the snow accumulation, as discussed above. Furthermore, precipitations are not measured. Finally, perturbations due to riming are frequent on the Antarctic Plateau, especially regarding radiation sensors (see discussion in the paper), which induces gaps in the in situ data set. So, any attempt to run Crocus from meteorological conditions provided by automatic stations would require a blending with an other source of forcing data, likely from a reanalysis. This would considerably limit the interpretation of the results and is a study by itself. A previous study by Brun et al. (2011) discussed the performance of Crocus in the simulation of snow surface temperature at Dome C. Using local observations as input forcing data, Crocus hourly surface temperature exhibited a RMSe close to 1°C over a 11- day period and a negligible bias.

By showing in the paper (p 69 line 26 to page 70 line 13) that a small change in the critical Richardson number makes it possible to compensate prescribed perturbations of forcing air temperature (-2 to +2 °C), we implicitly recognize that error compensations in the simulations may partially explain the good performance of Crocus, in spite of the likely warm bias of ERA-interim air temperature. Nevertheless, the hourly surface temperature simulated by the model exhibits a quite reasonable performance (RMSe smaller than 4°C only) over a very large area of Antarctica where meteorological conditions vary a lot, both in space and time. This strongly limits the likeliness of significant error compensations since the very same configuration of the model is run over the whole domain.

4. Is the biases identified in ERA-Interim also present in the new product ERA- Interim/LAND data set?

Answer : Figure R1.5 presents the bias of ERA-i/land Ts with respect to hourly MODIS Ts over the 2000-2010 period. ERA-i/land Ts shows a warm bias ranging from +4 to +6°C on most of the Plateau under clear-sky conditions. The ERA-i/land Ts bias

is slightly lower than the ERA-i Ts bias but is still quite significant. ERA-i/land Ts bias and ERA-i Ts bias also exhibit the same feature presenting their minimum in winter and their maximum in summer around the central part of the Plateau. These results confirm the overestimation of ERA-i/land Ts observed between 2009-08-02 and 2009-09-16 at South Pole (Figure 7 of the paper).

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/8/C536/2014/tcd-8-C536-2014-supplement.pdf

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